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QUALITATIVE ANALYSIS OF AIRBORNE MAGNETOMETER DATA: THE ARABIAN SHIELD, KINGDOM OF SAUDI ARABIA

by

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PREFACE

In 1963, in response to a request from the Ministry of Petroleum and Mineral Resources, the Saudi Arabian Government and the U. S. Geological Survey, U. S. Department of the Interior, with the approval of the U. S. Department of State, undertook a joint and cooperative effort to map and evaluate the mineral potential of central and western Saudi Arabia. The results of this program are being released in USGS open files in the United States and are also available in the Library of the Ministry of Petroleum and Mineral Resources. Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government agencies. The Government of Saudi Arabia makes this information available to interested persons, and has set up a liberal mining code which is included in "Mineral Resources of Saudi Arabia, a Guide for Investment and Development," published in 1965 as Bulletin 1 of the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, Saudi Arabia.

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ABSTRACT

A qualitative analysis and interpretation of magnetic data obtained from airborne magnetometer and scintillometer surveys of the Precambrian Arabian Shield, Kingdom of Saudi Arabia, show that some rock units and geologic features exhibit characteristic magnetic expressions and anomalies. Circular to elliptical anomalies are attributed to younger intrusives or less commonly older masses, stocks, and plugs of granitic rocks. The linear anomalies may be expressions of faults, lineation trends, or dike swarms. Reconnaissance exploration for evidence of mineralization are recommended in the vicinity of some of these anomalies.

INTRODUCTION

A qualitative analysis and interpretation were made from magnetic data obtained from the airborne magnetometer and scintillometer survey of the Precambrian Arabian Shield, flown and compiled in 1961-62 and 1965-66 by the consortium consisting of Aero Service Corporation, Hunting Geology and Geophysics Limited, Lockwood Survey Corporation Limited, and Arabian Geophysical and Surveying Company. The study provides additional information on the tectonic framework and areal geology of the Arabian Shield and locates areas for future reconnaissance exploration of potential mineral deposits. J. Maillard, Bureau de Recherches Géologiques et Minières, undertook a similar study and his results were issued in April 1968.

METHOD OF STUDY

The analysis and interpretation of the aeromagnetic and radiometric maps provided by the contractor were facilitated by using photo-positive composite mosaics (reduced to a scale of 1:500,000) as overlays on geologic maps of the U.S. Geological Survey Miscellaneous Geologic Investigation series. Much of the shield area covered by the geologic maps is shown on plate 1. The photo-positive mosaics were examined for distinctive magnetic patterns and anomalies, and the areal geology and tectonic features interpreted from these expressions were compared with the geology on the maps and on subsequent published and unpublished geologic maps. Magnetic anomalies which could be interpreted as resulting from geologic settings commonly considered to be conducive to the localization of mineral deposits were compared with the geology of those areas. The magnetic maps were also studied in areas of ancient mines and known mineral localities to determine if any magnetic expression could be related to the mineralization. The major fault zones, probably of the wrench-fault type, are now schistose and talcose and probably were too impermeable to have been the channelways for post-deformation mineralization solutions. Tension faults on the flanks of the larger wrench-fault zones were apparently open and in many places are the loci of mineralization.

DISCUSSION OF RESULTS

General description of magnetic features

The magnetic data on the maps are relative and depend upon the magnetic polarization and susceptibility contrast between any given rock unit and the adjacent or enclosing ones. Consequently, the appearance of the magnetic patterns and anomalies at various localities on the aeromagnetic maps may differ somewhat from the following descriptions.

The Tertiary and Quaternary basalt and andesite flows exhibit a magnetic pattern that is characterized by rather small, closely spaced, high amplitude, crinkly birds-eye wavelets not unlike a ripple-marked effect. The intensity of the magnetic expression may differ depending upon the thickness and composition of the flows.

The andesite facies of the Halaban Formation has a magnetic pattern similar to that of the flows, even though it is somewhat more subdued. It is also magnetically heterogeneous because of the presence of interlayered metasedimentary units in the flows and the metasedimentary facies. Consequently the magnetic pattern differs with the composition, thickness, and structure of the formation. Because of this difference, outcrops of the Halaban Formation cannot be demarcated consistently with a high degree of confidence. The Shamar Rhyolite has a magnetic expression similar to but much less than the andesite facies of the Halaban Formation.

In the southern part of plate 1 the Murdama Formation consists mostly of quartz, sericite, chlorite, and biotite tuffaceous schists and exhibits a magnetic pattern similar to that of the andesite facies of the Shamar Rhyolite but the anomalies are less intense.

Precambrian amphibolite schist commonly produces moderate-to-high-amplitude circular to elliptical anomalies over the outcrop areas.

Large areas of granite, granite gneiss, and metasedimentary rocks mostly show a rather flat, expressionless magnetic pattern, whereas younger intrusive or older granitic stocks and plugs commonly exhibit filled or open, circular anomalies.

The presence of dike swarms, lineations and foliations in rock masses commonly result in low-amplitude, narrow, elliptical anomalies.

Magnetic patterns and anomalies distinguishable on the photo-positive aeromagnetic mosaics are classified as follows:

1. Significantly different magnetic expressions indicative of lithologies having different magnetic susceptibilities.

2. Positive or negative linear anomalies tens to hundreds of kilometers long which are probably expressions of steeply dipping tabular geologic features such as major fault zones, lineations, or dike swarms in the shield rocks.

3. Linear anomalies several to tens of kilometers long exhibiting steep gradients which are probably indicative of structural trends, faults or shear zones, dikes, or lithologic contacts in the shield rocks.

4. Filled, circular anomalies are commonly in large areas of low to moderate expression that are indicative of younger intrusive or less commonly older stocks and plugs or xenoliths of higher magnetic susceptibility than the enclosing rocks.

5. Open, circular anomalies with steep gradients only on the edges are commonly in large areas of low to moderate magnetic expression that are indicative of younger intrusive or less commonly older stocks, plugs, or xenoliths with higher magnetic susceptibility along the edges of the bodies due to primary concentration of metasomatism of the enclosing rocks that have a lower magnetic susceptibility.

6. Open, circular anomalies with low magnetic expression are commonly in large areas of moderate to high magnetic expression which are indicative of younger intrusive or less commonly older stocks, plugs, or xenoliths with lower magnetic susceptibility than the enclosing rocks.

The most outstanding magnetic features are the linear anomalies. The magnetic linear trends expressed by long, steep gradients between areas of relatively high and low magnetic values are attributed to structural trends or faults which bring into juxtaposition rocks of different magnetic susceptibility and polarization. Shorter, less straight gradients may be caused by lithologic contacts without faulting.

The predominantly negative linear anomalies range in amplitude between 3,000 and 4,000 gammas, and the most numerous positive linear anomalies exhibit a maximum amplitude of about 3,000 gammas. These anomalies are probably an expression of steeply dipping, tabular features which may include major faults, shear zones, foliation, lineations, or dike swarms. They are expressed because of differences between the magnetic polarization and susceptibility of the geologic features and the enclosing rocks. There are several explanations for the abundant negative and positive anomalies and differences in their general expression. If the anomaly is due solely to induced polarization in the earth's magnetic field of a tabular feature of higher magnetic susceptibility than the enclosing rocks, the total intensity anomaly would be predominantly negative at this magnetic latitude, but the azimuth and inclination of the geologic feature would affect the shape of the anomaly. The anomaly might be due almost entirely to remanent magnetization of the tabular feature, and the positive or negative sense and general shape of the anomaly would be little affected by the magnetic latitude and the azimuth and inclination of the tabular feature in relation to the earth's present magnetic field. Also, the pre-existing magnetic minerals in the country rock may have

have been altered to nonmagnetic assemblages by hydrothermal solutions circulating through the inferred sheared and brecciated planar zones of weakness, thus creating a tabular feature with a sufficient magnetic susceptibility contrast to produce a detectable anomaly.

There is some parallelism of azimuth and coincidence of several of these linear anomalies or parts thereof with major mapped faults, lineations, and dike swarms in the shield rocks, but there is also a considerable deviation between the azimuths of the linear anomalies and many of the mapped faults. I do not think that this deviation eliminates the possibility that many of the linear anomalies are related to major tectonic features of the shield. The fact that many of the tabular geologic features inferred from the aeromagnetic data have not been recognized in the field may be due in part to magnetic differences which are not visually manifested. Similarly, faults, lineations, and dike swarms mapped in the field may be conspicuous but not detectable to the magnetic sensor.

Magnetic features of map areas

Area I.-- The aeromagnetic survey in the Al Lisan and Wadi Sawawin areas include part of the exposed Precambrian rocks in the southwest corner of the Wadi as Sirhan quadrangle mapped by Bramkamp and others (1964). Metavolcanic and metasedimentary rocks with older and younger granite masses are present, and they are transected by several prominent westerly to northwesterly trending faults.

The areal distribution of the metavolcanics and granites as inferred from the magnetic data is in agreement with the geologic mapping, and some of the linear anomalies shown on plate 1 are essentially coincident with the mapped faults although more faults are depicted on the map than are inferred from the magnetic data. Most linear anomalies trend northwest, and a few trend west. The strong, westerly trending linear anomaly L_1 in the southern part of area I (pl.1) is essentially coincident with a mapped fault. The magnetic data verify that the fault persists beneath alluvium in the wadi and also suggest that it continues westward along the coastline to the Gulf of Aqaba.

No particular area seems to exhibit any marked potential for the localization of metallic mineral deposits.

Area II.-- The survey covers most of the Northwestern Hijaz quadrangle mapped by Brown and others (1963a) except for the north and northeast parts where Tertiary and Quaternary basalt flows and Paleozoic sedimentary rocks crop out.

The Precambrian geology is complex, but can be generalized as consisting of three broad belts of different lithologies that trend northwest. The eastern belt is predominantly andesitic rocks of the Halaban Formation with some Hadiyah Slate and sericite-chlorite schist, all of which have been intruded by masses, stocks, and plugs of granite and granodiorite. The central belt contains mostly metasedimentary and metavolcanic rocks, primarily sericite-chlorite schist and greenstone, with some large masses of granite and granite gneiss and stocks and plugs of granite and granodiorite. The western belt is characterized by granitic rocks chiefly granite, granite gneiss, and granodiorite with bands of sericite-chlorite schist and greenstone. Northwesterly and westerly trending major faults and foliation lines are common particularly in the northern half of area II where the complex structural relationships apparently are along the westward extension of the Najd fault zone. Many of the faults appear to be of the wrench type.

Contacts between lithologies having considerably different magnetic susceptibilities, such as the basalt and andesite flows, some granites, and metasedimentary rocks, can be picked with reasonable accuracy from the aeromagnetic maps. In some cases, there is good correlation between the lithologic contacts depicted on the geologic map and the areas of different magnetic expression interpreted from the aeromagnetic map; in other cases some modification of the geologic map, based on the magnetic data, might be considered. The gross magnetic anomalies that are discernible provide only a suggestion of the geologic complexity of the map area. For example, numerous, irregularly-shaped plugs and masses of granite or syenite intrusive into the andesite of the Halaban Formation are depicted on the geologic map in an area approximately bounded by lat $25^{\circ}30'$N. to lat $26^{\circ}39'$N., and long 38°30'E. to long 39°00'E. Because of the strong magnetic expression of the andesite relative to the granite, the presence of only the larger masses is suggested by irregular areas of low magnetic relief. Any magnetic expression of the smaller granite or syenite bodies is obscured by the magnetic expression of the andesite.

Closed, circular anomalies A_1, A_2, and A_3 in the southeast quarter area II (pl.1) range in diameter from about 5 to 12 kilometers. Comparison between the size of the anomalies and of the intrusives mapped in these areas by Brown and others (1963a) suggests that the near-surface extent of the intrusives is larger than depicted on the geologic map. Anomalies A_1 and A_2 are over plugs of granite or syenite intruded into foliated sericite-chlorite schist. An intrusive is not shown on the geologic map in the vicinity of anomaly A_3, but subsequent work by Johnson and Trent (1968) revealed the presence of a diorite plug with smaller included and fringing bodies of granite and gabbro. The area of the anomaly was overflown on March 10, 1968, but no landing was attempted due to turbulent air conditions. From the air the rocks appear to be somewhat massive and are darkly stained and apparently altered. A slight airborne radiometric anomaly was obtained over the area. The intrusive and the adjacent rocks should be examined for evidences of mineralization.

A group of four, rather large, open circular anomalies, A_4, A_5, A_6, and A_7, are in the north-central part of area II and are attributed to granitic intrusives and amphibolite masses (pl.1). The geologic relationships are complex and include several ages of granite and granodiorite intrusive into belts of sheared and foliated greenstone and sericite-chlorite and amphibolite schists. The aeromagnetic data are too gross to reflect the detailed geology.

In the east-central part of area II (pl.1), several northwesterly trending linear anomalies are subtly displayed within the strong magnetic expression over the andesite of the Halaban Formation. The linear anomalies L_1, L_2, and L_3 converge at a point P_1 which is also the origin for a southerly trending linear anomaly. No faults are mapped in area II, but the linear anomalies are essentially parallel to the strike of adjacent belts of rock units, and they may result from magnetic lineations in the flows. The northeasterly trending linear anomalies north of the point exhibit no apparent relationship with the mapped geology. The area near the junction point of the linear anomalies should be checked in the field.

Along the southwest edge of area II, three prominent linear anomalies strike northwest. Two of these, L_5, and L_6, can be traced intermittently across most of the area, but the third, L_7, is essentially confined to the northern third of the area. The linear anomalies are not coincident with any mapped faults except along short segments of their trace. They are, however, essentially parallel to mapped faults, lineations, and belts of schistose rocks and are indiscriminately distributed over metasedimentary, metavolcanic, and igneous rocks. In the northern half of area II these linear anomalies are offset locally in a predominantly left-lateral sense along westerly to northwesterly trending linear anomalies and also where no anomalies are detectable. This area is along an extension of the Najd fault zone and is probably the locus of late, recurrent movement along the zone (pl.1). The northwesterly trending anomalies are also offset in both a left- and right-lateral sense along northeasterly trending linear anomalies. Interpretation of the offsetting relationships suggests that the northwesterly trending anomalies pre-date the west-northwesterly, westerly, and northeasterly trending anomalies. The linear anomalies are possibly along faults even though they are not coincident with known faults.

Area III.-- The aeromagnetic survey covers part of the Northeast Hijaz quadrangle mapped by Brown and others (1963b). The Precambrian rocks consist mostly of metasedimentary and metavolcanic rocks, and older and younger granite and granodiorite bodies. The granitic bodies are of several ages and have been mapped as synkinematic, as gneiss resulting from replacement of metamorphosed sediments, and as intrusive circular stocks, plugs, and ring dikes. Dikes of rhyolite or diabase intruded all Precambrian rocks with the exception of rhyolite flows and the plugs and stocks of the youngest granite. Most of them trend northwest, some trend north and northeast. The metamorphism ranges from greenschist to amphibole facies. Along prominent faults the sedimentary and volcanic rocks have been altered to sericite-chlorite and amphibolite facies. Lineations have a northerly trend or exhibit a circular pattern suggestive of concordancy with exposed or shallow igneous bodies. A part of the Najd fault zone is in the southeast corner of the area. Geological relationships are extremely complex, and the aeromagnetic maps only partly reflect this complexity.

The areal distribution of the major rock units and the general geological relationships depicted on the geologic map by Brown and others (1963b) are corroborated by the magnetic data. Because of the difference in magnetic expression of the large mass of granite in the northern part of area III, it is suggested that the mapped mass includes granite of more than one composition and possibly more than one age. Mapped areas of the Halaban Formation (Brown and others, 1963b) also exhibit locally a different magnetic expression which suggests a difference in composition of the flow rocks or possibly some interlayering of metasedimentary material.

In the west-central part of the area the magnetic expression of the Tertiary and Quaternary basalt flow suggests that this rock unit thins along the southeastern edge of the outcrop area and in places may consist only of remnant patches similar to those mapped south of the main area of basalt flows.

Some modification of the mapped areal extent of the synkinematic granite in the southeastern part of area III is inferred from the magnetic data. The magnetic expression of the granite consists of many strong, elliptical, easterly trending anomalies, whereas the adjacent metasedimentary facies of the Halaban Formation produces a much weaker magnetic expression. The abundant dikes of rhyolite and diabase that have been mapped in the granite are postulated to be the cause of the magnetic expression of the granite. Another possible cause might be that the granite is a result of granitization of an older somewhat mafic rock, and the anomalies are caused by remnant magnetic minerals in the granite. Some of the areas mapped as the metasedimentary facies of the Halaban Formation very likely contain intercalated metavolcanics for the magnetic anomalies are somewhat similar to those expressed by flow rocks.

A broad, northwesterly trending anomaly A_1 with a low magnetic gradient extends for a distance of about 70 kilometers over a northwesterly trending wadi tributary to Wadi ar Rimah. The anomaly has almost straight sides with steep gradients, and subtle linear anomalies continue for a distance of about 25 kilometers to the northwest L_1 along strike with the southwest edge of the anomaly and to the southeast L_2 along strike with the northeast edge of the anomaly (pl.1, area III). Anomaly A_1 transects several different lithologies shown on the geologic map by Brown and others (1963b), and the magnetic expression on either side of the anomaly is suggestive of andesitic flow rocks or possibly granitized equivalents thereof. The anomaly may result from erosion in the tributary wadi of a rather thin plate of Halaban rocks and gneissic granite leaving a low magnetic susceptibility rock as the bedrock in the wadi thus putting into juxtaposition rocks of markedly different magnetic susceptibility. Scattered remnants of the Halaban Formation in the wadi are shown on the geologic map. An alternative cause for the anomaly may be movement along boundary faults of a horst which brings into juxtaposition rocks of markedly different magnetic susceptibility. The extension of linear anomalies beyond the main anomaly A_1 suggests that faulting may be partly responsible for the presence of the anomaly. Whatever the cause, the area should be re-examined in the field.

Anomaly A_2 ranges in width from about 1 to 5 kilometers, is about 170 kilometers long, and essentially overlies a belt of sericite-chlorite schist. This lithology, of indeterminate age, is apparently common along wrench-fault zones and is derived from sediments and basic flow rocks. Compared to the magnetic expressions over other areas of sericite-chlorite schist in the same part of area III, however, the anomaly overlying this belt is more intense. This would suggest a higher grade of metamorphism in the belt and the development of hornblende and probably some magnetite. The belt of schistose rocks, as inferred from the magnetic data, is probably the locus of a fault zone and it should be checked in the field for any evidence of mineralization.

Circular anomalies A_2 through A_{10} are over stocks or plugs of granite. The intensity and character of circular anomalies depend on the magnetic susceptibility contrast between the causative bodies and the surrounding rocks, and the anomalies may be either filled or open. Where surrounded by rocks of much higher magnetic susceptibility, the anomalies are very subtle if the causative bodies are small.

Open circular anomaly A_{11} is attributed to a granite plug which probably connects at a shallow depth with the same body of granite exposed to the northeast. Open circular anomaly A_{12} may be due to a rounded mass of granite different in composition and possibly in age from the enclosing granite mass. Closed circular anomaly A_{13} is attributed to an intrusive granite plug whose surface exposure is rather small but which is larger at depth. The intrusive has produced lineations and small faults in the enclosing Murdama Formation concordant with the intrusive. Circular anomaly A_{14} may be due to a near-surface granite plug of similar composition.

Several northwesterly trending linear anomalies L_3, L_4, and L_5, are shown in the southeast part of area III (pl.1). They essentially overlie mapped faults which are in and parallel to the Najd fault zone.

In the southwest corner of area III several linear anomalies including L_6 and L_7 are in the near vicinity of a complex of mapped faults. Linear anomaly L_6 essentially overlies a thrust fault which brings andesite of the Halaban Formation into juxtaposition with chlorite schist. The edge of the fault plate as inferred from the magnetic data and indicated on the geologic map are coincident over a distance of about 20 kilometers, but the linear anomaly extends intermittently to the northwest for another 20 kilometers.

Magnetic linear anomalies ranging in length from a few kilometers to as much as 20 kilometers are in the vicinity of mapped dike swarms and have the same general orientation. The anomalies are attributed to these bodies. Other linear anomalies over areas of metasedimentary and metavolcanic rocks are essentially parallel to lineations.

The Murdama Formation in the vicinity of anomalies A_{13} and A_{14} should be investigated as possible loci for mineralization.

Area IV.-- The aeromagnetic survey covers the southwestern parts of the geologic maps of the Wadi ar Rimah quadrangle (Bramkamp and others, 1963) and Northern Tuwayq quadrangle (Bramkamp and Rimirez, 1958) where Precambrian rocks are exposed except for small areas in the southeast and southwest corners. Metasedimentary and metavolcanic rocks, mostly sericite and chlorite schists and amphibolite, are in scattered patches and masses throughout the area. These rocks are intruded by younger masses, stocks, and plugs of granitic and intermediate composition. A large part of area IV is underlain by an older synkinematic gneissic granite. The igneous rocks are cut by many dikes of rhyolite, diabase, and andesite of diverse orientation although most of them trend northwest and west. Lineations are particularly common in the schistose Murdama Formation, and they commonly suggest a concordant relationship to intrusive masses. Prominent northwesterly trending faults are in the southwestern part of area IV.

Several of the more common lithologies exhibit a rather characteristic magnetic expression, which are granite gneiss, andesite facies of the Halaban Formation, granite with numerous dikes, and granite intrusives as stocks and plugs. In general, between rocks of markedly different magnetic susceptibility and polarization, the magnetic data may aid in more closely defining some map contacts and to extrapolate the bedrock distribution of the rock units under alluvium. Compositional differences in the volcanic rocks of the Halaban Formation or some interlayering of metasedimentary units are suggested from the magnetic pattern. An atypical magnetic expression is over the Murdama Formation in the vicinity of lat 25°45' to 26°00'N. which is probably indicative of different facies of the formation.

Open circular anomaly A_1 overlies a granite plug and a part of an older granite mass to the northeast. The extent of the granite plug may be greater than mapped although it is possible that the magnetic susceptibility contrast between the granite masses is too small to permit delineating the boundary between them.

Circular anomalies A_2 and A_3 are attributed to fensters in the Hibshi Formation which expose the underlying granite.

Circular anomalies A_4, A_5, A_6, A_7, and A_8 overlie granite plugs and ring dikes and are attributed to these geologic features.

No intrusive bodies in the broad expanse of granite are indicated on the geologic map by Bramkamp and others (1963) in the vicinity of circular anomalies A_9 and A_{10}. Magnetic susceptibility of polarization contrasts are suggested, however, and these may be due to differences in composition within the granite mass or to granitic bodies of different composition and age which were not mapped.

Circular anomaly A_{11} is probably due to a rounded granite mass which would suggest some revision of the mapped configuration of the enclosing Halaban Formation in area IV.

Open, circular anomaly A_{12} appears to be caused by two plug-like bodies along the peripheries of which magnetic minerals have been emplaced in the enclosing rocks. Much of the area of the anomalies is covered by eolian sand, but it appears that the Murdama Formation was intruded by a younger granite with some metasomatism of the Murdama and the development of Farida Marble along the northern edge of the intrusive.

Open circular to elliptical anomaly A_{13} exhibits a strong magnetic expression around the periphery. The anomaly is over a mass of gneissic granite which is bordered by Murdama Formation on the east and west and by Farida Marble on the north. The gneissic granite, although considered older than the Murdama, may actually be a younger granite which intruded and metasomatized the adjacent Murdama Formation.

Circular anomaly A_{14} overlies a small granite plug with a peripheral fringe of diorite along the north edge.

Filled, circular anomaly A_{15} is over the amphibolite mass in the vicinity of Samrah with a short extension of the anomaly to the southeast in the direction of the ancient mines. The area of the anomaly is a likely target for exploration.

Filled, circular anomaly A_{16} is over an area where the bedrock is mapped as Permian Khuff Formation resting upon Cambrian and Ordovician Saq Formation. Precambrian sericite-chlorite schist may underlie these formations, but the magnetic anomaly does not appear to be due to this rock type. The anomaly has the appearance of one caused by a shallow igneous plug.

Linear anomalies up to a few tens of kilometers long such as L_1, L_2, L_3, L_4, and L_5 are over masses of granite containing numerous dikes, and are attributed to these geologic features. Other linear anomalies such as L_6 and L_7 which are over areas of metasedimentary and metavolcanic rocks generally parallel the direction of lineations in these rocks, and the anomalies may reflect the lineation and foliation of the magnetic minerals.

Several prominent linear anomalies which trend west to northwest including L_8, L_9, L_{10}, L_{11}, L_{12}, and L_{13} are not in the vicinity of any known faults. These anomalies are largely restricted to areas of extensive masses of granite and gneiss but extend into adjacent areas of weakly magnetic metasedimentary rocks. The cause of the anomalies is not known, but they may be due to rather prominent tectonic features.

In the southern part of area IV linear anomalies L_{14} and L_{15} are in the vicinity of a prominent mapped fault zone and are parallel to it. Although the anomalies and the mapped faults are not coincident, the anomalies are probably caused by faults in the zone.

Field investigations for possible occurrences of mineralization are recommended in the areas adjacent to the intrusives which cause anomalies A_4, A_5, A_6, A_7, and A_{14}; in the vicinity of the schistose rocks adjacent to linear anomaly L_6; and along the fault zone over which linear anomalies L_{14} and L_{15} are present, particularly in the vicinity of anomalies A_{12} and A_{13}.

The linear anomalies L_{17} and L_{18} coincide with major faults mapped by Bramkamp and others (1963). In the belt of Halaban Formation to the southwest of linear anomaly L_{17} only the north and south ends of the belt exhibit a magnetic expression that is suggestive of andesite in the Halaban. The rather flat magnetic expression in the remainder of the belt would suggest that a predominantly metasedimentary facies of the Halaban Formation is in this area or that the andesite of the Halaban has been largely removed by erosion.

The distinctive anomaly A_{17} overlies a small mass of amphibolite at the northwest end of linear anomaly L_{17}. The possibility of mineralization in the vicinity of this anomaly where andesite and amphibolite in the Halaban are adjacent to a fault should be investigated.

In the southwest corner of area IV numerous rather pronounced, elliptical anomalies trending generally northwest are over areas mapped as granite. The granite is described on the map by Bramkamp and others (1963) as a gray, biotite-hornblende granite with numerous westerly to northwesterly trending dikes of rhyolite, diabase, and andesite. The dikes may be responsible for the magnetic pattern which is not typical of the granite in this area. The possibility should also be considered that this rather uncommon expression of the granite might be attributed to partial granitization of andesite in the Halaban with a considerable amount of magnetic minerals preserved to produce an anomalous expression of this character and intensity. The numerous dikes of widely different composition may in reality express different degrees of granitization in the older volcanic rocks along previously established lineations.

Area V.-- The aeromagnetic survey covers most of the geologic map of the Southern Hijaz quadrangle by Brown and others (1963c). The Precambrian rocks include primarily metamorphosed mafic igneous rocks, volcanics, and sediments retrograded to the green schist facies, intruded by felsic and intermediate igneous rocks, and granitized by gneissic granite. Greenstones, sericite-, chlorite-, and amphibolite-schists generally are in elongated belts trending north or northeast, and the intrusive igneous and granite gneiss masses are irregularly-shaped bodies, stocks, or plugs. Most of the meta-igneous and igneous rocks are cut by dike swarms of rhyolite, diabase, and andesite which most commonly trend northeast or northwest. Lineations and foliations in the metamorphic rocks have a northerly or northeasterly, northwesterly, and westerly strike; locally they exhibit a concordant relationship to intrusive bodies. Mapped shear zones or faults have a northwesterly to northeasterly strike.

Parts of the photo-positive aeromagnetic mosaic were apparently overexposed when it was produced with the result that only the heavier isograms were preserved. Nevertheless, it is possible to distinguish between the areas of more extensive rock units with marked magnetic susceptibility contrast such as the metamorphosed mafic igneous rocks, the chloritic and amphibolitic schists, and the granitic and metasedimentary rocks with reasonable confidence.

The magnetic expression of the Tertiary and Quaternary lava flows is distinctive, and the edges of the flows can be easily demarcated from the magnetic data. The expressions of the metavolcanics and the granites are sufficiently distinct so that the contacts between these rocks, which are commonly marked by steep magnetic gradients, can be determined quite accurately. The character and distribution of magnetic anomalies in the Sahl Rakbah and Al Jarad in the west central part of area V suggests that a metavolcanic and granitic bedrock underlies this extensive area of coastal plain surficial deposits.

The magnetic expression of the belt of the Wadi Lith series in the southern part of area V is not uniform throughout the belt. This relationship may suggest retrograde metamorphism to lower rank with concomitant decrease in the amount of magnetite or a higher percentage of intercalated metasedimentary rocks locally or thinning of the series locally.

Circular anomalies A_1, A_2, A_3, and A_4 are over plug-like bodies of granite (pl.1, area V). The anomalies are either filled or open depending upon the susceptibility contrast between the granite and the enclosing rocks. The near-surface extent of some of these granite plugs can be defined quite accurately from the magnetic data.

The inferred circular anomaly A_6 in the south-central part of which magnetic data are missing is interpreted as resulting from an intrusive granite plug.

Filled, circular anomaly A_{17} is over a small gabbroic plug which is bounded by ring-like segments of granite.

Circular anomaly A_8 is over a mass of granite and granite gneiss and may result from a difference in the composition of the mass.

Filled, circular anomaly A_9 is over an intrusive plug of granite.

Filled, circular anomaly A_{10} is centered over small patches of granite intrusive into sericite and chlorite schist. The pattern and intensity of the anomaly suggest that the causative body is of relatively shallow depth.

Linear anomaly L_1 overlies a narrow belt of andesite in the Halaban Formation between two granitic masses. Linear anomaly L_2 is near the contact of the andesite in the Halaban Formation and granite but extends beyond the contact into an area of alluvium which suggests that this contact persists in the bedrock. The group of northerly to northwesterly trending linear anomalies L_3 parallel lineation trends in the andesite of the Halaban Formation and granodiorite. The linear anomalies also are in areas of these lithologies wherein no trend lines are mapped, and it is reasonable to extrapolate the trend lines into these areas on the basis of the presence of the linear anomalies. Over part of its length, linear anomaly L_4 is almost coincident with a prominent mapped fault, and over the remainder of its length it is essentially parallel to but offset slightly from it.

The magnetic features which are probably of greatest tectonic significance are the northwesterly trending linear anomalies which are in the west part of area V (pl.1). These linear anomalies extend unbroken for distances ranging between 10 and 100 kilometers and extend intermittently along strike for distances up to 250 kilometers. They are essentially confined to a belt 50 kilometers wide. The continuity of the anomalies is apparently not broken by intrusive plugs of granite dated at 535$\pm$ million years from Rb/Sr isotope ratios (Brown and others, 1963c) suggesting that the causative geologic features are younger than this.

The segmented group of prominent linear anomalies L_5 does not overlie any mapped faults or lineation trends except locally in the northwest part of area V (pl.1). Likewise, only one fault is coincident with a short segment of the linear anomaly L_6, and no other northwesterly trending faults are known in the vicinity. Either these linear anomalies are not caused by faults or lineation trends in the basement rocks or the evidence for these features is not conspicuous in the rocks.

Linear anomaly L_7 is offset locally. No linear anomalies suggestive of faults were noted on the mosaic of the magnetic maps in the vicinity of these offsets, but a major northeasterly trending fault is mapped at one locality.

The northeasterly trending linear anomaly L_8 transects greenstone and granodiorite. No obvious displacement of or by the intersecting group of linear anomalies L_5 could be seen on the photo-positive mosaic of the magnetic maps. A reconnaissance investigation for evidence of mineralization should be made in the vicinity of lat 26°16'N.; long 39°40'E.

The linear anomalies L_9, L_{10}, and L_{11} are essentially coincident over segments of their length with a prominent mapped fault which strikes northeast. If the complex of linear anomalies in this area is due to faults, then the single mapped fault is probably a zone of northeasterly trending faults which have been locally offset in a right - lateral sense by movement along younger easterly trending faults.

The northwesterly trending complex of linear anomalies L_{12} probably results from a major tabular feature which cuts across rocks of different ages and is apparently younger than any of the rock units. Along part of its length, linear anomaly L_{12} is essentially coincident with a prominent mapped dike. The anomaly is probably due to dike swarms along a major tectonic feature of the shield rocks.

The complex of cross-cutting linear anomalies L_{13} overlies an area of intensely faulted granite gneiss. The orientation of the anomalies and of the faults is essentially the same but in only a few cases are the interpreted anomalies coincident with the mapped faults. The anomalies are attributed, however, to faults and dikes in the area.

Linear anomaly L_{14} is over a northerly trending belt of sericite and chlorite schist. The trend of the anomaly parallels the belt, lineations in the belt, and boundary faults. The anomaly may be due to foliation, a shear zone, or fault in the schist.

The linear anomalies in the complex L_{15} are parallel to but not coincident with faults mapped in the area, and the anomalies are attributed to these features.

Areas in which investigations are recommended for indications of mineral occurrences include: the area of linear anomalies L_9, L_{10}, and L_{11} and particularly where L_9 and L_{10} are apparently offset; the area along and adjacent to linear anomaly L_{12}; the areas of sericite-chlorite schists and amphibolite schists adjacent to the complex linear anomaly L_{13}; the belt of sericite-chlorite schist along linear anomaly L_{14} and particularly at the north end in the vicinity of anomaly A_9; the faulted area of sericite-chlorite schist and greenstone in the vicinity of linear anomaly complex L_{15}; and around the gabbroic intrusive which causes anomaly A_8.

Although extensive magnetite mineralization is known at Methgal, lat 22°42'N.; long 39°51'E. and is very probably a result of hydrothermal activity along a prominent fault zone, no magnetic expression of the fault is discernible on the photo-positive magnetic mosaic. The contact between the greenstone and the diorite-granodiorite on either side of the fault zone can be demarcated on the basis of the different magnetic expressions of the two lithologies. Scattered deposits of base-metal sulfide mineralization has been reported along this fault zone and in the belt of greenstone to the west. This area should be investigated more thoroughly.

Area VI.-- The aeromagnetic survey includes all of Southern Najd quadrangle which has been mapped by Jackson and others (1963). The area is underlain mostly by metasedimentary and metavolcanic rocks including primarily sericite-chlorite schist, slate, chlorite schist, greenstone, and andesite which have been intruded by and deposited upon both younger and older masses and plugs of granite, granodiorite, diorite, and granite gneiss. The granite gneiss and some of the metavolcanic rocks are commonly cut by rhyolite, diabase, and andesite dikes. Lineations and faults strike northwest, north, and northeast in the south half of area VI (pl.1).

In the northern part of the area the geology is dominated by the Najd zone which trends northwest. Very complex structural relationships are depicted to the northeast of the Najd fault zone involving faulting and shearing of metavolcanic and metasedimentary rocks, development of gneissic granite, intrusion of stocks and plugs of later granite, and emplacement of dikes of various ages chiefly in the granitic rocks. Southwest of the Najd fault zone the Murdama Formation is essentially absent but the metasedimentary facies of the Halaban Formation is common, and gneissic granite is in most of the western half of this area (Jackson and others, 1963). Fewer faults are indicated southwest of the Najd fault zone, but strong lineations are mapped in the basement rocks, and the granites contain many dikes.

The magnetic expressions of several of the more common and widespread rocks are rather characteristic, and these data should be helpful in more closely defining lithologic contacts particularly in those areas where the rocks are covered by surficial sand and gravel. Differences in the magnetic expression and intensity over mapped areas of greenstone and greenschist suggest that these units include both metavolcanic and metasedimentary facies or that the composition of the metavolcanic rocks is not uniform.

In the southwest corner of area VI the mapped approximate contact between greenstone and granite lies somewhat west of the contact that might be inferred from the magnetic data. Revisions of the areal distribution of granite, diorite, and sericite and chlorite schist in the south-central part of the area should also be considered.

The filled, circular anomaly A_1 is over an area in which alluvium, Murdama Formation, and two small plugs of intrusive granite were mapped by Jackson and others (1963). From the appearance of the anomaly it can be inferred that an intrusive granite plug larger in size than suggested from the two mapped plugs is under a thin cover of the Murdama Formation and may be the bedrock beneath the alluvium in the wadi.

Open, circular anomaly A_2 is over a somewhat circular mass of gneissic granite, which is bounded on the northwest quadrant by Murdama Formation and around the remainder of the periphery by andesite in the Halaban Formation and alluvium. The flat magnetic gradient in the center of the anomaly is attributed to the granite, and the magnetic highs and lows with steep gradients around the periphery are attributed to the higher magnetic susceptibility of the border zone of the granite or of the metasedimentary and metavolcanic rocks in contact with it. The relative intensity of the magnetic field over the granite and metavolcanic rocks is about the same and over the metasedimentary rocks it is slightly lower. Interpretation of the magnetic data suggests that the granite is younger than the enclosing rocks, although it is listed as being older on the geologic map.

Open, circular anomaly A_1 overlies a granite plug which is surrounded by rocks of the Murdama Formation. The narrow high around the periphery of the anomaly is attributed to higher magnetic susceptibility of the metasedimentary rocks in contact with the granite or of the border facies of the granite.

Closed, circular anomaly A_4 is over Murdama Formation. Inasmuch as this formation does not exhibit a magnetic pattern of this type in any place where it is exposed, it is suggested that the anomaly is caused by a granitic stock or plug beneath the Murdama Formation.

Closed, circular anomaly A_5 is for the most part over a semicircular plug of granite that intruded gneissic granite to the north and Murdama Formation to the south. The strong, crescent-shaped magnetic high along the south perimeter of the anomaly overlies the Murdama Formation and may be due to alteration of the enclosing rock adjacent to the intrusive.

Open, circular anomaly A_6 overlies an area of granite and alluvium. The total intensity of the anomaly is slightly less than that of the magnetic field surrounding it, and the perimeter of the anomaly is marked by a weak low. The anomaly is attributed to a granite plug with a slightly lower magnetic susceptibility intruded into an older granite mass. Open, circular anomaly A_7, which overlies an area of alluvium where one very small outcrop of granite is mapped, appears to be caused by a similar geologic situation.

In the east half of area VI many granite plugs of various sizes intrude granites and metavolcanic rocks, but either no magnetic anomaly results because of a lack of magnetic susceptibility contrast in the granite masses or a masking of the anomalies is over small plugs by the magnetic susceptibility of the metavolcanic rocks.

Subtle circular anomalies A_8, A_9, and A_{10} overlie small intrusive granite plugs, but the magnetic expression of the bodies is almost masked by the stronger magnetic expression of the andesite facies of the Halaban Formation. Many small granite plugs are mapped in the same general vicinity, but no magnetic expressions of these bodies are discernible.

Filled, circular anomaly A_{11} overlies a part of a large mass of granite gneiss, and the anomaly may be due to a circular body of different composition and possibly different age in the gneiss.

The segmented, linear anomaly L_1 is an extension of linear anomaly L_{17} in area IV. (pl.1), and over much of its course it essentially coincides with a prominent mapped fault. The offset situation near the south end of the linear anomaly suggests right-lateral displacement along a northerly trending fault. However, such structural relationships are not indicated on the geologic map.

The south end of linear anomaly L_2 is over a prominent mapped fault but the anomaly and the fault diverge toward the northwest.

Linear anomalies L_3 and L_4 overlie prominent mapped faults in the Najd fault zone over much of their respective lengths, although other faults in the zone have no apparent magnetic expression. Where the fault passes through areas of andesite, the magnetic expression of the fault is obscured by the stronger expression of the flow rocks.

The group of linear anomalies L_5 in the southeast corner of area VI transect granite and andesite in the Halaban Formation as is parallel to the lineation trends and dikes in these rocks. The group of linear anomalies L_6 also transect granite and rocks of the Halaban Formation, including both the metavolcanic and metasedimentary facies. The anomalies are essentially parallel to lineation trends in the basement rocks, and in one case an anomaly is coincident with a prominent fault. The anomalies are attributed to zones of magnetic minerals along lineations or faults. Rather broad, magnetic linears consisting of many small, circular to elliptical anomalies overlie belts of andesite between granite masses. The magnetic data are of little help in defining the geologic relationships for the magnetic susceptibility contrast between the lithologies is very slight.

The group of linear anomalies L_7 is over a mass of granite and andesite and transects both lithologies. The trend of the anomalies is parallel to that of the numerous dikes mapped in the area by Jackson and others (1963), and the anomalies may be due to swarms of these dikes.

Linear anomaly L_8 overlies a mapped fault along much of its length but only partly reflects the complexity of the fault. The fault brings into juxtaposition the andesite facies of the Halaban Formation with granite and Murdama Formation.

Strong magnetic gradients are along the north and south perimeters of anomaly A_2 where the granite is in contact with andesite in the Halaban Formation. Shearing and lineation in the andesite parallel to the granite contact are indicated on the geologic map by Jackson and others (1963). The strong magnetic expression around the periphery of the anomaly may be caused by magnetic minerals concentrated in the shear zones of the Halaban or around the borders of the granite. On the southeast perimeter of the granite-andesite contact a northerly trending fault is mapped. The area of the granite-andesite contact, particularly in the vicinity of the fault, should be investigated for evidences of mineralization.

A prominent zone of northwesterly trending linear anomalies L_9 ranges in width from about 6 to 13 kilometers and extends intermittently along strike for about 170 kilometers (pl.1). These anomalies are over a prominent fault zone and locally are coincident with parts of the mapped faults. Linear anomalies which are predominantly negative are believed to be caused by rather steeply dipping tabular bodies which could be faults or shear zones. Linear anomalies expressed by steep gradients are probably due to contacts between lithologic units of different magnetic susceptibility and polarization. These units may be in juxtaposition because of conformable relationships, intrusion, or faulting, although faulting would seem to be the most reasonable mechanism in this area.

Linear anomalies L_{10}, L_{11}, and L_{12} are intermittent, and locally along their length are essentially parallel to and coincident with prominent faults mapped by Jackson and others (1963). The linear anomalies are attributed to major tectonic features, possibly faults or shear zones, in the shield rocks. Visual evidence of these features may not be apparent in all of the exposed rocks, but the presence and persistence of the features is strongly suggested by the linear anomalies.

Linear anomaly L_{13} is over a northerly trending belt of chlorite schist and may be caused by lineations in the schistose rocks. Linear anomaly L_{14} is attributed to a similar phenomenon.

Linear anomaly L_{15} is locally parallel to and coincident with a northwesterly trending fault mapped by Jackson and others (1963).

Linear anomaly complex L_{16} is in the vicinity of a complexly faulted mass of chlorite schist in the southwest corner of the area VI. Locally, some of the linear anomalies are coincident with some of the mapped faults.

The Najd fault zone is the major tectonic feature in the area mapped by Jackson and others (1963) and appears to consist of wrench-type faults. As a matter of standard procedure, a reconnaissance exploration investigation for evidences of mineralization should be made along the fault zone and adjacent to it where tension fractures would likely have formed, and also along the linear anomalies.

Most of the area southwest of the Najd fault zone is composed of masses and belts of sheared metavolcanic and metasedimentary facies of the Halaban Formation, gneissic granite which may have been formed by granitization of the Halaban, intrusive masses and plugs of granite of more than one age, and numerous dikes of felsic and mafic composition and of diverse ages. Very probably, the whole complex has been subjected to intense folding and faulting. A reconnaissance exploration investigation is recommended in the andesitic belts and adjacent gneissic granites in the area southwest of the Najd fault zone.

Area VII.--The survey area north of lat $21^{\circ}30'$N. includes only the western part of the Southern Tuwayq quadrangle mapped by Bramkamp and others (1956), inasmuch as Precambrian rocks crop out only there. Metavolcanic and metasedimentary rocks, primarily schists with large masses of granite gneiss and some intrusive stocks and plugs of later granite are exposed in the area. The schistose rocks exhibit a westerly to northwesterly trend, and a segment of the northwesterly trending Najd fault zone is mapped by Bramkamp and others (1956) in the southern part of area VII. The structural complexity of the northwestern part of the area is suggested from the distribution of the metavolcanic and metasedimentary rocks, the numerous intrusive masses and plugs of granite and diorite, the prominent northerly trending fault, and the subsidiary faults parallel to and also bifurcating from it.

Slight discrepancies exist between the areal distribution of the sericite-chlorite schist and granite in the northern part of area VII and of the Halaban Formation and granite in the southern part as indicated on the geologic map and as inferred from the magnetic data. In the southern part of area VII, the magnetic expression of the granite is greater locally than the Halaban Formation which suggests that the metasedimentary facies of the latter is more prominent than the metavolcanic facies or the formation is considerably thinner than it is a few tens of kilometers to the west.

A prominent linear anomaly L_1 is essentially coincident with the Najd fault zone and extends southeast under the Permian Khuff Formation and Quaternary alluvium to the edge of area VII. The magnetic expression immediately north of the fault zone is more indicative of a mafic rock than granite as mapped by Bramkamp and others (1956). The layered intrusive rocks which are included in the granite, however, may be responsible for this magnetic expression.

In the northwest corner of area VII, linear anomaly L_2 overlies the northerly trending fault that is the western boundary of the structurally complex belt of andesitic and fine-grained dioritic rocks, flows, and intrusives. This belt, which includes the ancient mines of At Taybi, Umm ad Dabah, and Al 'Amar and the magnetite deposit at Jabal

Idsas, has been investigated rather thoroughly by the Directorate for evidences of mineralization.

A reconnaissance exploration investigation for evidences for mineralization should be made along the Najd fault zone and adjacent to it where tension fractures would have likely formed.

Area VIII.-- Tihamat Ash Sham aeromagnetic survey included most of the geologic map of the quadrangle by Brown and Jackson (1958). The Precambrian rocks consist mostly of metasedimentary and metavolcanic rocks including sericite-chlorite schist, marble and quartzite, quartz-feldspar schist, and greenstone that are in elongated masses and belts which trend north. Intruded into these rocks are masses and plugs of granite, granodiorite, diorite, metadiorite, amphibolite, and gabbro. Rhyolite, diabase, and andesite dikes are in most of the rocks. Most faults, dikes, and lineations strike north and northwest, and fewer faults strike east and northeast. The geologic map depicts the area as being very complex structurally.

The magnetic expressions of the metavolcanic and mafic rocks are sufficiently different from the magnetic expressions of the metasedimentary and felsic rocks to delineate the approximate boundaries between rather large masses of these rock types. Between rock units of about the same magnetic susceptibility and particularly where the units are in narrow belts, delineation is not reliable. The bedrock configuration of the Baid Formation and some interlayered(?) andesite and diabase can be traced by their magnetic expression under the gravel and sands of the coastal plain.

Linear anomalies L_1, L_2, and L_3 are marked by steep gradients and local highs and lows along the gradients. The anomalies strike northwest and are essentially continuous along strike for distances ranging from about 10 to 80 kilometers (pl.1). They are not coincident with faults mapped by Brown and Jackson (1958) except locally along short segments of their trace, but they are essentially parallel to lineations in the schistose rocks. The anomalies are attributed to major tectonic features, possibly faults or shear zones.

In the southwest part of area VIII, linear anomaly L_4 is essentially coincident with a prominent mapped dike.

Greenstone and schistose rocks in the vicinity of the prominent linear anomalies should be investigated as possible loci for mineralization.

<u>Area IX.</u>-- The aeromagnetic survey covers the western part of the Asir quadrangle, mapped by Brown and Jackson (1959), where the Precambrian complex constitutes the bedrock. Geological relationships are very complex and involve a variety of metasedimentary and metavolcanic rocks of different original composition and metamorphic facies including conglomerate, slate, quartzite, marble, chlorite-sericite schist, amphibolite schist, and greenstone. These rocks are in irregular

patches and in elongated belts with a northerly trend and have been intruded by younger masses and plugs of gabbro, diorite, granodiorite, and granite some of which subsequently have been metamorphosed. Igneous lithologies make up most of the bedrock. Many dikes of rhyolite, diabase, and andesite intruded most rocks and are broken and displaced by prominent faults. The faults, dikes, and lineations strike predominantly north to northwest and rarely northeast. Boundary faults between different rock units are common.

Parts of the photo-positive aeromagnetic mosaic were apparently over-exposed when produced with the result that isogram line weight is not uniform throughout, and in some parts of the mosaic only the heavier isogram lines were preserved. Areas of different magnetic expression cannot be delineated reliably. The magnetic data corroborate in only a general way the configuration and distribution of the more extensive rock units. Narrow belts of rock commonly cannot be delineated from the magnetic data and particularly if the magnetic susceptibility contrast between the rock units is small.

Many circular stocks and plugs of young granite are depicted on the geologic map by Brown and Jackson (1959) but very few exhibit a discernible magnetic expression. This is partly due to their small size and masking by the magnetic expression of the enclosing rocks.

Filled, circular anomaly A_1 overlies a granite plug.

Complex circular anomaly A_2 is over two granite plugs which are close together and may be connected at a shallow depth.

Circular anomaly A_3 essentially overlies a mass of gneissic granite, but the magnetic expression is not the same as that over a large mass of gneissic granite to the east. The anomaly is probably caused by a plug of younger granite.

Open, circular anomaly A_4, which is over a granite plug, is quite subtle but distinguishable from the magnetic expression of the surrounding greenstone.

Circular anomalies A_5 and A_6 are over granite plugs.

Linear anomalies are essentially restricted to the southern part of area IX and are discernible only in areas of low magnetic intensity. None of these anomalies are coincident with mapped faults nor are they as numerous. Some of the linear anomalies are over rock masses wherein dike swarms and lineations are common. The anomalies strike essentially parallel to these geologic features and are attributed to them.

Linear anomaly complex L_1 in the southwest corner of the area IX trends northwest and consists of several anomalies which are primarily over a belt of chlorite-sericite schist and amphibolite schist. The anomalies may be attributed to lineations in the schistose rocks or to major tectonic features.

Linear anomalies L_2 and L_3 trend east and probably are caused by tabular features. However, no fault, shear zone, dike, or lithologic contact with an easterly orientation is mapped in their vicinity.

The belt of schistose rocks in the vicinity of linear anomaly complex L_1 should be investigated for evidences of mineralization.

SUMMARY

The qualitative analysis and interpretation of the aeromagnetic data provide additional information on the tectonic framework and areal geology of the Arabian Shield. Certain rock units exhibit distinctive magnetic patterns that aid in identifying and demarcating them from adjacent units particularly when the magnetic polarization and susceptibility contrast is significant. The magnetic inhomogeneity of several of the rock units, expressed by differences in the magnetic expression, suggest the presence of rocks of different composition and possibly of different age.

Two broad categories of anomalies are distinguishable on the magnetic maps: circular to elliptical anomalies, and linear anomalies. The circular to elliptical anomalies are attributed to younger intrusive or less commonly older masses, stocks, and plugs of granitic rocks having a different magnetic polarization and susceptibility than the enclosing rocks. It is suggested that the linear anomalies are expressions of faults, lineation trends, and dike swarms. The fact that many of the faults or lineation trends inferred from the aeromagnetic data have not been recognized in the field may be due in part to magnetic differences which are not manifested visually. Similarly, faults and

lineations mapped in the field may be conspicuous but not detectable to the magnetic sensor.

The major fault zones, probably of the wrench-fault type, are now schistose and talcose and may have been too impermeable to provide channelways for post-deformation mineralization solutions. Tension faults on the flanks of the larger wrench-fault zones were apparently open. The tension faults are often the loci of mineralization, and these areas are recommended for reconnaissance exploration investigations. Similar studies should be undertaken on the periphery of intrusive bodies particularly in contact with metavolcanic rocks.

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